CHAPTER 4

DEMONSTRATION OF VARIABILITY - A CASE STUDY FROM SAXON SOUTHAMPTON

INTRODUCTION

The general methods described above were used for the examination of the marine shells from the Six Dials site of Saxon Southampton where oyster and other marine species such as winkles, mussels, cockles and whelks were recovered. These shells occurred in various context types including primary ditch fills, pre-street levels, wells, road or yard surfaces and pits. The initial aim of the study was to examine a selection of samples to determine whether variation existed between the marine shells from the different types of context or between samples from different phases of the occupation of the area. Having demonstrated that variability, evidence was then sought that might indicate the reasons for such variation. Oyster shells were the most numerous and were studied in the greatest detail.

METHODS

A hundred and four samples from different contexts were examined in the first instance but only thirteen of these, which contained thirty or more individual oysters, were analysed in detail. The shells were washed, identified, sorted into species and counted. Oysters were divided into left and right valves. Oyster shells were measured and infestation and other characteristics recorded.

PRELIMINARY ANALYSIS

For each measurement type, i.e. left valve maximum width (LVMW), left valve maximum length (LVML), right valve maximum width (RVMW), and right valve maximum length (RVML) the minimum, maximum, mean, standard deviation and standard error of the mean were calculated for the thirteen larger samples. The results were tabulated, first arranged according to context type and then according to phase.

Size frequency histograms were drawn for maximum width of left and then right valves of the same thirteen samples to show the size structure of the individual samples. Two sample _t_-tests were carried out to determine whether the samples were significantly different in size. The results were tabulated first as matrices showing simply which samples were significantly different from each other and secondly as matrices showing the actual _t_-values of those samples that were significantly different. An analysis of variance was undertaken to show how the thirteen samples related to each other with regard to size. The computer diagrams showing this analysis for each of the four measurements have been included.

The numbers of oyster shells in which the infestation/encrustation characters were recorded as present were tabulated to compare the frequency of occurrence in different context types and then in different phases. Histograms of the percentage occurrence of each type of infestation for left and right valves in each phase were drawn. The rate of infestation for each context type was also illustrated by histograms of relative frequency.

The presence and position of cut marks or notches, relative thickness and weight, deformities, colouring, state of preservation and type of cultch (where clearly indicated) were also recorded but not analysed.

RESULTS

Numbers

Tables 4.1.a, 4.1.b, 4.1.c list the individual contexts examined and present the numbers of the most common marine mollusc shells found in them. Table 4.2 shows the numbers of oyster shells in all the samples examined from the different context types. The greatest numbers of oyster shells were found in pit contexts (minimum number of individuals (MNI) 2266), followed by road/yard surfaces (MNI 523), wells (MNI 112), pre-street levels (MNI 15) and primary ditch fill (MNI 1) respectively. Many of the shells were too damaged to be measured. The highest percentage of unmeasurable shells came from the pits (28.9% of left valves and 27.3% of right valves). This high figure may in part be due to post-excavation damage sustained by shells from SOU 169 T2 Pit 8454 c.8600 (39.2% of left and 35% of right valves unmeasurable). The high proportion of unmeasurable right valves from pre-street levels was based on too small a sample to be significant.

Figure 4.1 gives histograms to illustrate the relative frequency of left and right valves of oyster shells respectively in the different context types.

Table 4.3 shows the numbers of commonly found types of marine mollusc shell from all the samples examined from each context type. These species were oyster (Ostrea edulis L.), winkle (Littorina littoralis (L.)), mussel (Mytilus edulis L.), cockle (Cerastoderma edule (L.)), whelk (Buccinum undatum L.) and dog whelk (Nucella lapillus (L.)). Only measurable oyster shells were included in this table. The primary ditch fill and pre-street contexts were impoverished in both species and numbers, the former with only one oyster and the latter with shells from a few more oysters and five winkles. Wells contained 5% of the measurable oyster shell examined and 0.1% of winkles (4). Road surface contexts had around 20% of all measurable oyster shell, 0.6% of winkles (18). 3.5% of mussel valves (11), and 2.4% cockle (1 valve). Pit contexts were overwhelmingly most abundant in numbers and species with approximately 75% of all measurable oyster shells (MNI 1612), 99% of winkles (2963), 95.9% mussels (304 valves), 97% cockles (41 valves) and all whelks (12) and dog whelks (8). Figures 4.2, 4.3 and 4.4 illustrate the relative percentage of winkles, mussels and cockles in each context type in that order.

Size

Basic information

The thirteen contexts which contained a minimum number of thirty individual oysters were selected for a detailed study of size. Tables 4.4, 4.5, 4.6 and 4.7 show basic data and calculation summaries for the left valve maximum width, left valve maximum length, right valve maximum width and right valve maximum length measurements respectively of these larger samples arranged in order of context type. In Table 4.4 for left valve maximum width measurements, for example, it can be seen that there was a great deal of variation between the samples. The minimum measurements ranged from 26mm in context 8600 to 57mm in context 896. The maximum measurements ranged from 93mm in context 9820 to 125mm in context 8709. The smallest mean was 66.8mm in context 9901 compared with the greatest of 90.7mm in context 896. The standard deviations give an idea of how the frequencies were grouped around the mean, while the standard error of the mean is a prerequisite for later calculations.

For all measurement types, the well context contained shells with the highest mean size. Most of the larger samples examined were from pits which, incidentally, had been in close proximity to each other on site. The lowest mean size was found for shells from context 9901 (pit 8474). The two contexts from road resurfaces had shells with means close to average. The same type of relationships are shown in Tables 4.5, 4.6 and 4.7.

Size structure of samples

To illustrate more vividly the way in which the size structures of the different samples varied, a series of histograms was drawn up for the maximum width measurements of right and left valves of all thirteen samples. They can be seen in Figures 4.5.a to 4.5.m and 4.6.a to 4.6.m. The numbers of shells recorded with each measurement in each sample were plotted in groups of 5mm and expressed as a percentage to aid comparability since the sample sizes were all different. Width is almost invariably greater than length. Left valves are usually wider than right valves. This would appear to be a natural relationship in oysters. The exceptions, possibly the right valves in context 9820, could be worthy of further investigation since unusual ratios of measurements might reflect a change in shape characteristics.

The histograms show that most of the samples had, surprisingly perhaps, approximately (statistically) normal distributions, e.g.

context 896 in Figure 4.5.a and context 8686 in Figure 4.5.k. Some samples did not conform to this apearance, e.g. context 9959 Figure 4.5.j. This may be related to sample size. The larger the sample, the more likely it is to have a normal distribution of sizes. Most samples show a fairly compact distribution with a range of sizes over 50 to 60mm, e.g. context 242 Figure 4.5.c and context 896 Figure 4.5.a, though the minimums and maximums varied. Context 667 Figure 4.5.d was a sample with a far greater spread of sizes over an 80mm range.

Size comparisons by t-test

However, the histograms are basically descriptive and it is not possible to accurately judge from these or the Tables 4.4 - 4.7 whether the samples are significantly different in statistical terms. Therefore, the size frequencies were used in two sample *t*-tests comparing the sample from each context with that from every other context. Where the *t*-value obtained had a value greater than 2, the two samples being compared could be considered significantly different.

Matrices were drawn to show which samples were significantly different for each set of measurements (Figures 4.7.a to 4.7.d). A + sign signifies those samples that were different. The matrices illustrate very clearly that two samples in particular were indeed very different from all others. For every measurement type and every comparison the sample from context 896 was significantly different; and in every comparison but one the sample from context 9901 was different. There was also an indication that contexts 9820 and 667 might be distinct.

Matrices were then drawn to show the actual *t*-values for significantly different samples (see Figures 4.8.a to 4.8.d). These showed the degree to which the samples were different. Many samples were indeed different according to the criterion of *t* = more than 2. However, all *t*-values obtained in comparison of samples with context 896 were consistantly high. Figure 4.8a shows values ranging from

5.26 to 17.21. Similar values are found as well on Figures 4.8.b to 4.8.d. In the same way, for samples compared with that from context 9901, *t*-values were also higher than elsewhere but not with the degree of magnitude shown by 896.

Size comparison by analysis of variance

The size frequencies were further manipulated in an analysis of variance to show the relationship of these two very different samples, from contexts 896 and 9901, to the other samples. The computer output relating to this analysis of variance for each of the four measurement types is reproduced in Figures 4.9.a to 4.9.d. The column headed 'level' gives the context numbers of the samples. They are arranged randomly. To the right is a diagram in which the asterisks represent the means and the dashes and brackets the extent of the confidence intervals (based on pooled standard deviations). The base line shows measurement in millimetres. The base line varies for each diagram. It is immediately obvious that contexts 896 and 9901 stand apart from the other contexts in each of the four figures. Shells from 896 are characteristically larger than average, while those from context 9901 are typically smaller than normal. The remaining samples form a fairly tight group generally exhibiting a limited range of means. The sample from context 9820 seems also to be different on Figure 4.9a for LVMW but this does not hold true for the rest of the measurements which show a progressive tendancy to 'normality'.

Finally a histogram was drawn combining the frequencies of the two distinct samples. Figure 4.10 illustrates the two samples with the greatest and the smallest size characteristics from the Six Dials excavations of Saxon Hamwic, and shows the distinct peaks of their 'curves' and that their distributions do in fact overlap.

Size comparison of samples by phase

A summary of basic data and calculation results for each of the four measurement types for the larger samples of oyster shell, with the contexts arranged in phase order, can be seen in Tables 4.8 - 4.11.

Those contexts belonging to the 'mid' phase of 750 - 850 A.D. are not arranged in age sequence. Most shell-containing contexts belonged to the 'mid' phase; while only single contexts represented the early (700 - 750 A.D.) and late phases (850 - 900 A.D.). It is interesting to note that the only context with a larger sample belonging to the early phase was, in fact, from context 896, a well. This sample has already been shown to be significantly different from all the other samples and contains larger than average shells. The other distinctly different sample, from context 9901, was contained within the large mid-phase group and was characterised by smaller than average shells.

All of the pit samples from SOU 169 but one, and the two road surface samples, belong to the mid phase. The late phase is represented by the largest deposit of shells recovered, those from SOU 169 pit 8454 context 8600. The lack of more detailed dating precludes the possibility of accurately detecting the presence or otherwise of trends of change in size.

Infestation

The evidence that can be detected in archaeological oyster shells for infesting and encrusting organisms has been described earlier in Chapter 3. The degree of infestation or encrustation in oyster shells from the larger contexts from the Six Dials site is shown in Table 4.12 with the information grouped into context types; and in Table 4.13 grouped according to phase. The count of right and left valves affected by each type of organism is given both as numbers and as a percentage of shells affected in each group.

Infestation comparisons between context type

Table 4.12 shows that the shells from the well context were affected by fewer infestation categories than the other contexts. Barnacles and Bryozoa were absent. Polydora was recorded most, Polydora hoplura was the dominant form with almost double the percentage of shells affected by Polydora ciliata. Sand tubes of Sabellid worms were the next most common, followed in importance by boreholes, Cliona and calcareous tubes.

All infestation types were recorded from the road surface contexts. Again, the most significant form was Polydora. For left and right valves combined, Polydora hoplura and Polydora ciliata were present in virtually equal proportions, the percentage of shells affected by P. ciliata being almost double those affected in well contexts. Small percentages of shells were affected by the remaining infestation types.

The pit contexts show a reduction in the numbers of shells with burrows of the Polydora species compared with wells and road surface contexts. Polydora hoplura again seemed to be the dominant form. Bryozoa (Polyzoa) was found in greater numbers of shells than before but the rate of infestation was actually still low. Only small numbers of shells were affected by the other organisms. Figures 4.11, 4.12 and 4.13 illustrate by way of a histogram the relative proportions of the different infestation characters for each context type. The left valves are invariably more affected than right valves. From a comparison of the three figures, it can be seen that the well context (c.896) is distinct. It is the only context type without barnacles or Bryozoa; and it is the only one with high percentages of sand tubes and boreholes. The relative frequency of the two Polydora species varies.

Infestation comparisons between phases

Table 4.13 shows the rate of infestation/encrustation in oyster shells from larger samples arranged by phase. Over all, the shells from the early phase were the most infested, followed by the mid phase and then the late phase which was relatively infestation free.

Six infestation characters were recorded from the early phase, all eight from the mid phase and four in the late phase. The histograms of Figures 4.14 and 4.15 present this same information. There is a trend for both the incidence and number of types of infestation to be reduced with time. This could have implications with regard to the type of populations being exploited.

CONCLUSIONS OF PRELIMINARY STUDY

The aim of this study was to determine whether variation existed between the samples of oyster shell and other marine molluscs from various contexts and phases of the site. Variability has been demonstrated in the numbers of shells, their size and infestation.

The numbers of oyster and other shells differed greatly from context to context. Of the hundred and four samples examined, only thirteen had a minimum number of individual oysters of thirty or more. The small numbers in most of the contexts could possibly represent the remains of individual meals (1 man/meal). If credence is given to the allusions in literature to the consumption of large numbers of oysters by one person at one sitting, (one of Napoleon's generals regularly ate a hundred before breakfast, Bismark was seen to swallow twelve dozen at a time, and Prince Otto ate 175 at a Colchester feast etc), even the shells from the well (MNI 106) and road surfaces (MNI 549) might represent a relatively small contribution to the diet in terms of man/meals. However, in all probability, they do represent the food of more than a few people because not all the oysters recovered from the site were actually examined. The high bulk of shell to meat weight, at least 5:1, can give a misleading idea of the importance of oysters in the diet.

The large quantity of shells from the late-phase pit context 8600 (MNI 1111) is worthy of mention. The indications are that this deposit accumulated very rapidly. If this large sample is an isolated occurrence, then oyster populations cannot have been regularly exploited on a large scale. It would be interesting to determine whether similar deposits occurred elsewhere on the site.

Winkles, mussels and cockles also occurred sporadically in small numbers, but with occasional large pockets. Winkles usually appeared in very small numbers but there were three substantial deposits of 2164, 220 and 145 shells. Mussels were mostly under ten specimens per sample but one sample had 232 individuals. It can be noted here that other species such as saddle oysters (*Anomia ephippium* L.) and carpet shells (Venerupis sp.) did occur infrequently, but were not included in the tables since their inclusion with the more usually edible species is likely to have been accidental and they would have played no major part in the diet. The vast majority of non-oyster species were found in pit contexts.

Variability was also demonstrated by the metrical and infestation analysis for oyster shells. The samples from two contexts, SOU 99/W36 context 896 (well) and SOU 169 T2 pit 8474 context 9901, have been shown as distinctly different in size from the other samples; the former being larger and the latter smaller.

It has also been shown that context 896 has a distinct pattern of infestation. Considering all samples, a possible trend has been detected for a change in size from larger to smaller oysters over time. There was a noticeable reduction in infestation from early to late phases. It is only possible to speculate at this stage whether these changes might be the result of improving stock (development of cultivation), or changes in seabed conditions, or exploitation of different populations of oysters.

It is possible that a more detailed study of these samples and others from Hamwic, the examination of data relating to modern populations of oysters in Southampton Water and the Solent, together with knowledge of hydrological and climatic changes, might provide a basis on which to build up a clearer picture regarding such points of interest as the source of marine molluscs used as food at Hamwic and the possibility of the development of some kind of oyster culture.

In an attempt to answer some of the questions arising from the preliminary examination of the oyster shells from the Six Dials site in the preliminary work, the data were re-examined in depth along with information from various sources concerning the environment of Southampton Water and the Solent at the present time and in the past.

These further examinations concerned such factors as age distribution, growth rate, variations in shape, cultch types, variation in infestation, and variation in the associated types of molluscs. The effect of temperature on growth rate was discussed, along with shape in relation to substrate, the relevance of cultch, the significance of infestation types and frequency, and the importance of associated molluscs. An interpretation of the results of both the preliminary and further investigations of the Hamwic shells was then attempted.

FURTHER INVESTIGATIONS INTO THE REASONS FOR VARIABILITY

In the preliminary study of the oyster shells from the Saxon site of Six Dials in Southampton, the size analyses showed that two contexts contained shells that were, in statistical terms, significantly different in size from the remaining eleven contexts. Those from SOU 99 W36 context 896 of the early phase (A.D.700 - 750) were on average much larger, and those from SOU 169 T2 pit 8474 context 9901 of the mid phase (A.D.750 - 850) were generally much smaller than the shells from the other contexts. In an attempt to find out why the sizes were different in these particular contexts, the right valves from all the larger samples were re-examined so that age could be estimated along with the maximum width measurement. The shape of the oysters was also considered along with the objects (cultch) on which they had settled, the frequency of infestation and the associated molluscs. All results were examined in the light of what we know today about the history of the physical and biological environment of Southampton Water and the Solent.

Age distribution

The percentage of shells in each year group was plotted as a histogram. The features held in common by the samples from the selected contexts can be seen in Figure 4.16 and Figure 4.17 with age groups containing less than 5% of the sample omitted. In most samples the majority of shells belonged to the four-year group with a single peak of distribution. Usually, most of the shells were found in a relatively narrow band of year groups (when the outliers are discounted as in Figure 4.17), for example, 2-6 or 3-7 years.

The one-year and two-year groups were generally absent. Context 896, which was composed of larger than average shells, adhered to this general pattern. However, some samples did not fit this scheme. Contexts 11151 and 11275 (from SOU 169 pit 8469) had multiple peaks (at 4, 6, 7 and 4, 7, 8 years). The same samples also had a wide spread of age groups (4-10 and 3-12 years). Clearly, there was something very different about these two samples. Also, context 9901 (from SOU 169 pit 8469) which by statistical analysis was shown to contain smaller shells than normal for the site, showed a peak in the two-year group with a spread of 1-4 years. Its neighbouring context 9959 peaked at four years with a range of 4-6 years.

Since the distribution of age groups in context 896 conformed to the pattern possessed by the majority of samples, differences in age composition could not account for the significant difference in shell size. Context 9901, on the other hand, had a unique distribution of very young oysters, and this in all probability was the reason why the shells in the samples were significantly smaller in size. It is interesting to note that age groups of the neighbouring context 9959 from the same pit complemented those of 9901. Maybe these two samples had been derived from a common sample that had undergone some kind of sorting either prior to, during or after burial.

Contexts 11151 and 11275 had a peculiar age composition that was not easy to explain. In size, they were not significantly different from most of the samples, but obviously they had distinguishing characteristics.

Growth rate

The observed size differences in the samples of oyster shell from Hamwic might be attributable to variations in growth. The ages of the shells and their maximum width measurements were used to calculate absolute growth rate. The mean measurement for each age group was plotted on a graph to produce a curve of absolute growth rate for each of the contexts. The immediate picture obtained by examining the individual curves was confusing. A clearer image was created by grouping the data of contexts belonging to the same feature, usually a pit, and replotting the results. Also the mean measurements of age groups represented by less than 5% of the sample were omitted in the interests of accuracy and clarity. On the same graph, curves were plotted for context 896 (a well context from SOU 99); 242 and 667 (road or yard surfaces from SOU 99); pit 8454 (context 8600); pit 8469 (contexts 11151 and 11275); pit 8474 (contexts 8568, 9820, 9901 and 9959); and pit 8576 (contexts 8686 and 8709). The result can be seen in Figure 4.18.

There appear to be three fairly distinct growth-rate regimes. The shells of context 896 grew at a much faster rate than the others, especially in the first four years. This could possibly account for the large size of the shells. The majority of samples had shells with a more moderate growth rate. The curves overlapped and were nearly identical in places. Finally there was a pit group with slightly lower growth rates than most. This was pit 8469 with contexts 11151 and 11275. These contexts were remarkable for their unusual age composition although size frequencies were normal. The frequencies and low growth rate could be linked.

Variations in shape

Shape was assessed by calculation of linear regressions. The linear regression of length to width was used as a measure of the degree of regularity of shell shape for each sample. When length for width measurements are plotted for each specimen then a scatter diagram of points is created. If the length equals the width for each shell, then the points would be lined up diagonally across the graph to form a slope with an angle of 45 degrees. The greater the discrepancy between the two variables, the smaller or greater the angle of slope would be. Since the relationship between length and width is not the same for each shell, the points will usually be arranged either side of the theoretical slope line. This is called the "scatter". If all the points are close to the theoretical slope line, a low degree of scatter, then the correlation co-efficient will be close to unity. The lower the correlation co-efficient, the wider the scatter of points. Table 4.14 shows the slopes, correlation co-efficients and scale of roundness for shells from the Hamwic samples. The samples with the lowest degree of slope are thought to be less regular or round. Context 3571 and context 8709 had the roundest or most regular shape and context 9959 had the least round or regular shape. The degree of scatter was between 0.75 and 0.9 for most samples; the correlation between the two variables was quite high.

Cultch types

The Hamwic oysters were attached to a variety of cultch types such as old oyster shells, shell debris, gravel, cockle shells, mussel shells, tingles and saddle oysters.

Variation in infestation

Infestation of the shells was not severe. Figure 4.19 shows the degree of infestation by sample. Figure 4.20 shows degree of infestation by phase. The highest proportions of Polydora infestation were recorded in contexts with predominantly thicker shells (such as contexts 11151, 11275, 242, 667 and 896). The lowest density of Polydora was found in samples characterised by thin shells (for example, 8568, 9696, 8709, 9901 and 9959). Polydora hoplura was the dominant form in the early phase; P.hoplura and P.ciliata were approximately co-dominant, on average, in the mid phase; while P.hoplura reassumed dominance in the late phase. On an individual context basis, P.ciliata was seen as dominant in contexts 242, 8686, 8709, 9901 and 11151, but substantially so only in 242.

Evidence of Cliona celata, the boring sponge, was found in small quantities in all but two samples (namely 9901 and 11275). It only reached 5% or more in such thick-shelled samples as those from contexts 667, 896, 9959 and 11151.

The calcareous tubes of Pomatoceros triqueter were present in small quantities on shells in half the samples, (242, 667, 896, 8568, 8686, 8709).

The sand tubes typical of Sabellaria spp were seen mostly in negligible quantities on thick shells in all but five samples. However, a high frequency was recorded in context 896 (7.2%).

Barnacle plates and bryozoan seamats were absent, or present in very small numbers, in most samples except for context 9901 where they were the dominant types of infestation.

The only substantial quantities of boreholes occurred in thick-shelled samples such as contexts 896, 9959, 11151 and 11275. The fastest and slowest growing samples showed an equal proportion of healed-over boreholes. It may be recalled that the slow-growing samples, 11151 and 11275, exhibited an anomalous age composition.

Variation in associated molluscs

Various marine mollusc species were found in association with the deposits of oyster shell at Hamwic. Winkles, mussels and cockles were the most common of the edible species. Small numbers of whelks, dog whelks, netted whelks, tingles, saddle oysters, tellins, carpet shells, variegated scallops and the odd limpet and periwinkle occurred. The small types, at least, would probably have been more an accidental inclusion than a deliberate contribution to the diet.

Only winkles and mussels occured in any significant quantity. Generally, the large numbers of winkles were found with very small numbers of oysters. Details can be seen in Tables 4.15, 4.16.a and 4.16.b. Context 8686 was one of the few that had a fair quantity of both oysters and winkles (159 and 60 respectively). There was only one large deposit of mussels, context 10951 (232). It is considered that mussels do not survive burial very well at Hamwic, and are therefore under-represented in the archaeological record. Fragments or blue 'fibres' are often all that can be observed. Therefore such a large quantity of relatively well-preserved mussel shells is unusual.

DISCUSSION

The effect of temperature on growth rate

The temperature of sea water is a reflection of the weather. Exact details and figures of the climate of the period under consideration, A.D.700 - 1000, are not available despite the fact that many investigations, such as deuterrium measurements on the wood material in dated tree rings of the bristlecone pine in the White Mountains of California by Dr Irving Freidman, and the oxygen isotope variations measured in the ice of north-west Greenland by Dr W. Dansgaard, have made exciting advances towards the elucidation of climatic patterns in this period of the past. An account of these and other methods, and the results obtained can be found in Lamb (1977). Lamb's own use of indices of weather derived from documentary sources provide the best idea about the general climatic trends for the region and period during which the Hamwic oysters were growing.

The weather is said to have been warmer than at present (Hill, 1981). The period showed a gradual improvement from the cool summers, floods, storms, cold winters and frosts that characterised the 6th and 7th centuries, to the start of the warmer Middle Ages (A.D.1000 - 1300) with its little "climatic optimum" in the 12th and 13th centuries. From A.D.700 to 1000 the summers were mostly warm, with occasional periods of cooler summers in the 9th and 11th centuries, a tendency to drought particularly A.D.920 - 940 and A.D.988 - 990, and dry, cold winters (Lamb, 1977).

This makes it possible to say that the high growth rate of the large shells in context 896 from the early phase of the site might well be the result of several very warm summers. To-day the climate of the region is intermediate between the "oceanic" of the west coasts of Britain and "continental" of south-east England (Barry, 1964). The highest temperatures on the English side of the Channel occur between Poole and Beachy Head, including the Solent. In the Solent there is a tendency for the winter water temperatures to be about 2 - 3 degrees centigrade lower than the mean 9^{o}C of the English Channel (these temperatures decrease westwards along the coast). This is still about 3^{o}C higher than those recorded in the renowned Essex oyster beds. In the early summer the temperatures are 3 - 4 degrees higher than the 16.5^{o}C mean of the Channel, which is about the same as the Essex beds (Holme and Bishop, 1980).

The flat oyster needs a prolonged period of warm weather in July or August while the spawning products are ripening, and a minimum of 15 - 16^{o}C to spawn. The good temperatures have to be maintained for 7 - 14 days to allow the larvae to develop properly before settling as spat. Oysters will spawn twice if conditions are optimum: once as a female and then as a male.

The group of samples with the moderate growth rate was mainly composed of shells from the mid phase (A.D.750 - 850) but also included the only late phase sample from pit 8454 (context 8600; A.D.850 - 900). The 9th century is thought to have experienced periods of cooler summers. At least some of the mid-phase samples may have dated from the 9th century along with context 8600.

The samples that showed the lower growth rate (contexts 11151 and 11275, pit 8469) belonging to the mid phase could be explained in terms of one or two exceptionally poor seasons. This would not be inconsistent with the facts because the indices of climatic trends are based on averages over several years. However, these samples also showed a peculiar age distribution. It is conceivable that temperature was not the only factor restricting shell growth.

Although growth rates could be explained in terms of temperature and its effects on metabolic rate, food supply and salinity, this may not be the sole plausible explanation of the observed differences. It has been mentioned that populations from different localities show distinct characteristics. It is possible that the three growth-rate curves represent oysters collected from three separate beds. This idea will be explored further.

Shape in relation to substrate

The shape of shells may be related to the type of substrate. There is some support to the idea that oysters growing on harder substrates, or in cultivated conditions, have shells that are fairly round and regular in shape; while oysters on softer substrates may have longer or less regular shells. If this is true for Ostrea edulis L. in British waters, then the shells from context 3571 at least and the other samples at the top half of the range of linear regression slopes may belong to oysters that grew on harder substrates. The shells from context 9959, at least, and the remaining six samples at the bottom end of the range may have grown on softer substrates.

The pattern of littoral or shore substrate types in Southampton Water and the Solent has been examined. The coastline of the region is low and characterised by mud flats which are particularly extensive in the western part. There is a gradation from the relatively wave-exposed east, at Selsey Bill in the East Solent for example, to places generally sheltered from wave action in the west part of that stretch of coast and the West Solent, although there is current scour in the Calshot and Hurst Spit regions (Holme and Bishop, 1980). The intertidal or littoral zone shows differences from place to place along the shore. On the open sea coast of West Solent there is a shingle spit at Calshot made of well-sorted smooth, round pebbles, cobbles and small boulders. As a sheltered area, it has a low-tide mud and gravel flat extending into the Solent.

The shores of the semi-exposed sea coast from Stokes Bay to Solent Breezes in the East Solent are protected and sheltered from wave action by the Isle of Wight. Finer sediments, less prone to movement, and high in organic content, have settled on the shore. The beaches have a typical profile of a steeply sloping bank of pebbles on the upper shore that grades into a mid-tide level of gently sloping fine, possibly silty, sand. A fairly firm surface of pebbles covers a mud and gravel mixture on the flat at low-tide level. The shores between Calshot Spit and Thorns Beach are physically similar to those for the eastern arm of the Solent.

The lower part of Southampton Water is a marine inlet in which the substrates are composed mainly of mud with varying degrees of inter-mixed sand, often with coarse surface shingle. The shores of the east side typically have three zones: a steep shingle bank, a moderate slope with shingle from the bank scattered over the surface, and a gently sloping mud flat of up to 1000m down to low water of spring tides. The shingle areas of the upper and middle shore are frequently replaced by saltmarsh on the shores of the west side of Southampton Water. Saltmarsh is also known to have occurred in the region of Southampton Docks before they were constructed over a hundred years ago. The saltmarsh nowadays is occupied by an immigrant species and its hybrids. On both sides of the Water the consistency of the mud substrate varies. Ridges of shingle or shell debris, depressions with surface water and areas of semi-liquid mud are features of the low tide flats, but the mud is generally softer on the western shore.

Among the inlets which are more estuarine in character are those of the Rivers Hamble, Itchen and Test. Their shores are often composed of highly organic mud and silt.

Firmer, sandier sediments are found more frequently on the south-east shores of Southampton Water. Near the mouth, in the Calshot and Solent Breezes areas, the substratum is particularly sandy and clay is also found. A bed of this stiff grey clay, that becomes more extensive southwards, outcrops between the Itchen and the Hamble. Since oysters prefer to grow on firm bottoms, these are the sort of places in which one might expect to find oysters. If firmer substrates are also linked to round or more regular-shaped shells, then these are also the locations in the Water that might yield such oysters (provided that all of the other special requirements for oyster growth are met, and that the conditions were the same in Saxon times).

Conversely, soft mud is typical of the head of the Water and the tributary estuaries, with particularly soft mud in the south-west near Fawley. Extremely soft mud would have been unsuitable for oysters, but given suitable hard objects on which to settle (such as pebbles or shells), oysters might in theory have grown on soft muds. These would have possibly been the less regular or longer shells.

In recent years oysters have been recorded in moderate abundance, frequently attached to small stones, at the base of Calshot Spit; and occasionally at Weston Shore and Hamble. An oyster fishery of 1200 acres is known to have been established at Hamble in 1868 (Philpots, 1890, 425 - 426). It was not a success as a breeding fishery because the strong out-going tide washed the larvae out into the open Solent, and no cultch for settlement had been laid down in the "channel". It was only a limited success for growing and fattening oysters because the oysters were put down "in the upper part of the channel" where they were washed away by floods or injured by "continual freshets" that caused a reduction in salinity. The oysters were then concentrated on the "lower ground" where they should have had a better chance of survival but, due to the heavy financial losses of the first years of the fishery, the owners appeared to have become discouraged and allowed the beds to fall into a neglected state. The Assistant Secretary for the Harbour Department of the Board of Trade reported, however, that there were plans to start again using cheap young oysters bred in the oyster ponds of the Medina and Newport Rivers of the Isle of Wight.

If conditions were the same in Saxon times, then oysters possibly could have settled near the Hamble. It seems unlikely that this would have been a self-perpetuating breeding population because of the unfavourable currents and salinity fluctuations. Such an oyster bed would have relied upon oyster spat from other beds, possibly in the more open waters of the Solent, for recruitment.

Coughlan et al (1972) stated that the general absence of oysters from Southampton Water (at that time, when a breeding population outside the Water in the Beaulieu River was producing larvae that had established themselves at Stanswood Bay near Calshot) must be due more to the presence of pollution than the absence of suitable substrate. Therefore it is possible to believe that oyster stocks in Southampton Water may have been greater in the past.

So far, only the variation in intertidal substrates has been considered. However, oysters also grow sublittorally in deeper waters. Because the Solent is a shallow body of water formed by the drowning of a number of river valleys (Steers, 1964), it is periodically dredged to maintain a clear channel for shipping, and so the bottom deposits are not everywhere in a natural state. The seabed is a patchwork pattern of various substrate types and combinations of them. In general terms the East Solent is mud with smaller patches of sand and gravel with mud while the West Solent has mostly gravel, with smaller areas of mud and sand in combination with the main gravel areas (Key and Davidson, 1981).

One obvious way in which the substrates today are different from those typical of even a hundred years ago is the presence of vast areas of slipper limpets (Crepidula fornicata (L.)) and their shells. This is a species that was accidentally imported to Britain along with American oysters sent to Brightlingsea, Essex in about 1880. They were first noticed in the Solent at Bosham and Hayling Island before the First World War and are now widespread. Although they compete with oysters for food and space to settle, and lay down a suffocating layer of mud, and have consequently been the target of vigorous attempts at extermination, their shells have nevertheless provided cultch on which oysters have been able to settle in increasing quantities in the past few decades, thus enabling the oyster to colonise areas hitherto unsuitable. Crepidula is recorded in all the Solent but is more common in the eastern part where banks of them occur with banks of old oyster shells in a ratio of about 3 to 1. In the West Solent and Stanswood Bay the opposite situation prevails with greater areas of old oyster shell compared to slipper limpet shells.

Oysters have probably always been more abundant, when present, in the West than the East Solent. Numbers of oysters in the East Solent have increased in recent years because of the additional cultch provided by Crepidula shells. Oysters in the West Solent have settled on gravel, where this is stable, and on stiff mud. Old oyster shells have consolidated the mud in places; and gravel, stones and shells provide cultch. Not all suitable substrates have populations of oysters; therefore conditions are not equally suitable for oyster settlement and growth. Oysters are currently recorded from Calshot (predominantly hard substrate) (H), Stanswood Bay (H), Thorn Knoll (predominantly soft substrate) (S), Bramble Bank (H & S), North Channel (S), Browndown Bank (S & H), Ryde Middle Bank (H), Mother Bank and Osborne Bay (H & S), Warner Shoal (H), Newtown Bank (H), Lepe Middle Ground (H), Sowley Ground (H), Lymington Bank (H) and Yarmouth Road (H) (see Figures 4.21 and 4.22 for locations of these and other places mentioned in the text). The hard beds can be seen to exist mostly in the West Solent.

It is clear from an examination of the literature on British oysters in general and the Solent oyster fishery in particular that stocks of oysters are subject to great fluctuations. Oysters from the Solent were not mentioned at all in the Commissioners' Report into the Seafisheries of the United Kingdom in 1865 (Key and Davidson, 1981). The Hamble oyster fishery has already been noted. The Isle of Wight may have been more consistently important for oyster production in the past. On a national scale, oyster stocks decreased due to over-exploitation at the end of the last century, and were virtually wiped out by some unknown cause in the 1920s (Orton, 1923). There was a slight recovery in the Solent area (Portsmouth harbours complex) in the late 1930s followed by further decimation in the severe winters of 1947 - 48 and 1962 - 63 (see, for example, Crisp, 1964; Waugh, 1964).

The large stocks in the Solent, at present, seem to be a phenomenon developed over the past fifteen years (1970 - 1985). These healthy stocks, in common with those in Poole Harbour, Dorset are of great importance because they are the only ones apparently not affected by Bonamia disease (Bannister, 1982; Bannister and Key, 1982). [N.B. Bonamia now in 1991 affects all stocks to a greater or lesser extent and, where natural populations survive they may only be fished for the table and are not relaid.]

It seems probable that the presence and abundance of oysters in the past would have varied just as much, being affected by changes in climate and local temporary extremes of weather, as well as diseases and over-exploitation. This might account for sporadic distributions through time as recorded by the archaeological evidence. The fact that oysters are now growing in the Solent is an indication that they might have done so in the past.

The relevance of cultch

Most of the recorded cultch types could have occurred anywhere in the region, but tingles and saddle oysters are not recorded live from Southampton Water. Shells of saddle oysters are sometimes washed up on the shore, particularly at the mouth of the Water, but probably live more frequently in deeper open water (Barnes, 1973). Tingles are found predominantly in the West Solent, but that does not discount the possibility that oysters settled on empty shells transported some distance from their place of origin (Key, 1982).

On the evidence afforded by shape, available substrate and cultch, the oysters from Hamwic could have come from a variety of locations in both the Solent and Southampton Water dependent only on the ability of the inhabitants to exploit the populations in various depths of water. If the Saxons of Hamwic could only collect oysters from intertidal populations by wading at low tides, then beds might have been available to them at such places in the Water as Weston Shore, Hamble Spit and Calshot as well as other places on the firmer mud areas of the eastern shore. Conditions on these low shore beds would have been favourable not only because of the substrate and local temperature regime, but also the double tides of the area would mean that the oysters were not exposed so long as in regions further along the coast to the west and east. In addition to this, provided that the same phenomenon was true then as now, the short time that the oysters were out of the water at low spring tides would have coincided with the early morning and evening (Holme and Bishop, 1980) so that the oysters would not have been subjected to the heat of the mid-day sun as in other areas, for example the Cornish beds. Ostrea edulis L. is more likely to be affected adversly by the heat than by cold (Yonge, 1960, 103). Since the local environment has been drastically modified by urbanisation, industrialisation, land reclamation, pollution, dredging, and the introduction of exotic species, more favourable conditions in the past may have encouraged oysters to grow on a larger scale.

If the Saxon people were able to exploit deeper-water oyster beds by dredging or "tonging" from boats (Yonge, 1960, 173), then they could have collected their shell fish from out in the Solent. (The speed of the tide in the Water would probably have been too great to allow oysters to settle in the deep sublittoral zone). The oysters, if and when present, would have been more abundant on the firmer beds of the West Solent although muddier regions at the mouth of the Water and in the East Solent might have had smaller quantities of oysters. West Solent oysters would have a tendency towards rounder, more regular shells compared with those from the East Solent.

Significance of infestation types and frequency

Polydora ciliata is more prevalent in oysters on hard substrates. Rounder shells are also thought to occur on hard bottoms. P. ciliata is, in fact, more commonly dominant in the six samples at the rounder end of the scale (see Table 4.14) in the ratio of four contexts with P. ciliata dominant to two with P.hoplura dominant. Polydora hoplura is believed to be typical of oysters on softer ground. The less round or less regular shells are similarly thought to be associated with soft substrates. P.hoplura is actually more often the dominant form in the least round shells (in the proportion of four contexts with hoplura to two with ciliata as dominant). Thus the evidence provided by these particular infesting organisms reinforces the idea that certain samples were collected from locations noted for harder or softer substrates in the area.

Evidence of Cliona celata, the boring sponge, cannot at present be related to the local distribution of the species.

Pomatoceros triqueter is only noted by Holmes and Bishop (1980) as occurring at Calshot Spit on stones, but by Esser (1972) from twelve out of twenty-seven stations sampled in the region including ones around the Hamble Estuary and Weston Shore.

Sabellaria worms occur on the middle or lower shore among boulders with sand in the vicinity on shores that are neither too exposed nor too protected; possibly also in estuaries (Barrett and Yonge, 1958, 82). Single tubes are known on shells or stones. Only one location in the Solent was noted for Sabellaria alveolata (Esser, 1972), but it is not known whether this is the species responsible for the tubes on the Hamwic shells.

Barnacle plates and bryozoan seamats might be indicators of an intertidal location.

From the distribution of boreholes in shells of different thicknesses, it is possible to theorise that the rate of survival from attack by predatory gastropods is greater in fast-growing oysters. The unusual age-group distribution in the slow-growing population could be a reflection of an unusually high mortality (low survival rate) as a result of predation in certain years. Thin-shelled populations might have been equally subject to such attacks but lacked the ability to withstand them so that attack mostly resulted in death.

Boreholes are made by Ocenebra erinacea (L.) and Nucella (Thais) lapillus (L.). The former grows abundantly in the West Solent at the present time (Key and Davidson, 1982) especially on the Sowley, Lymington and Lepe grounds. Dog whelks prefer rocky shores, of which the nearest equivalent is Calshot where a rocky-shore biota occurs on a sheltered and stable sediment shore (Holmes & Bishop, 1980). Barnes et al (1971) record dog whelks from four out of thirty-one stations in the West Solent but nowhere else in the region. It would seem likely that shells with boreholes originated in the West Solent.

Importance of associated molluscs

Winkles are known to occur on the semi-exposed sea coast from Stokes Bay to Solent Breezes. They are collected in large numbers commercially at Lee-on-Solent. They also live on the opposite shore between Calshot and Thorns Beach (Holme and Bishop, 1980). Winkles are also mentioned as abundant on intertidal flats at Hythe, Cracknore Hard, Millbrook and Weston Shore (Barnes 1971) while Barnes et al (1971) recorded winkles only rarely in the Solent. Winkles are intertidal and their presence with oysters in context 8686 may indicate that the oysters were also collected in the same intertidal location.

Mussels attach themselves to both natural and artificial hard objects on all the intertidal flats in Southampton Water, but are now particularly frequent at Royal Pier, Cracknore Hard, Hythe, Calshot, and Solent Breezes (Barnes, 1970; Barnes 1971a). Out in the Solent they were found in dredged samples from 17.6% of stations from the East Solent, 18.2% of stations in the mouth of Southampton Water, and 29.0% of stations in West Solent. So mussels are common both in and out of Southampton Water from the intertidal zone down to a few fathoms. The distribution of both winkles and mussels is too general to indicate which particular places were being used for collection.

Cockles are also abundant over the whole tidal flat but not many were recovered from Hamwic. Either cockles were not such a commonly-occurring species in the 8th and 9th centuries, or the Saxons had a dietary preference for other species.

INTERPRETATION OF RESULTS FROM PRELIMINARY AND FURTHER INVESTIGATIONS

There is some indication that the Solent area may have been subject to a eustatic rise in sea level, associated with the gradual warming of the climate in the Anglo-Saxon period which led to water from the ice-caps and glaciers returning to the sea (Hill 1980, 11). However, according to Stagg (1980, 19), there has been very little permanent land loss in historic times in this region, as evidenced by the Roman fort at Portchester, Roman Clausentum on the River Itchen and the medieval salterns near Lymington.

The climate is thought to have been a little warmer than we experience at present but subject, of course, to fluctuations. There is a possibility that increased temperatures and any slight rise in sea level may have resulted in higher salinity levels prevailing in the upper regions of Southampton Water.

Many changes have occurred in Southampton Water and the Solent, particularly in the last hundred years. These include land reclamation, especially at the head of the Water and along the western shore; industrialisation and urbanisation with accompanying pollution; dredging and the introduction of foreign species of plants and animals. Of all the man-made influences, only pollution may to some extent have had an impact on the distribution of oysters. The substrates at the head and on the west side of the Water, where most changes have taken place, are those least likely to have supported populations of oysters. Similarly the dredging of the shipping channel in the Water is thought to have had a minimal effect on the pattern of sediments on either shore (Spencer, pers. comm.) and the central part of the Water occupied by the channel has fast tidal currents that would make it unsuitable for oyster settlement anyway.

In short, there are good reasons for assuming that conditions affecting the distribution of oysters in Southampton Water and the Solent in the 8th and 9th centuries would have been similar to those prevailing in the 20th century. An attempt can be made, on this basis, to interpret the findings from a detailed examination of the oysters and other marine molluscs from Saxon Southampton by relating them to what is known about oysters, and other shellfish, and their distribution in the region to-day.

Variability has been demonstrated in the samples of oyster shell from Hamwic. Context 896 had larger shells and context 9901 had smaller shells than the rest of the samples. In order to see why there should be a difference, the shells were aged and placed in year groups for each sample. Most samples shared common characteristics, but the shells from context 9901 had much younger shells. The young age of the shells is therefore thought to account for the small sizes they exhibited. The sample of shells from its neighbouring context, 9959, from which it was separated by only a very thin layer in the pit, had a complementary distribution of ages. Perhaps these two samples had been derived from a common sample that had undergone sorting at some stage. Two other samples had a distinctive age distribution (11151 and 11275).

Growth rates were then calculated for the different contexts. Three fairly clear growth-rate regimes could be seen on the graph. The shells from context 896, which had the largest shells, had a high growth rate when compared with the majority which were closely grouped at a more moderate rate. The third group had a lower growth rate than the others, and this comprised the samples from contexts 11151 and 11275 which were noted as having an anomalous age composition. It was concluded that the high growth rate shown by the shells of context 896 was the main reason for their larger than average size.

The possible causes of the differences in growth rate were thought to include the effect of temperature on shell growth by way of its influence on metabolic processes, food supply and salinity. In other words, growth rate was considered to have been mainly influenced by climatic changes during the period under consideration.

The overall shape of oyster shells in the different samples varied. These variations in shape were believed to be a reflection of the type of substrate on which the oysters had been growing. It was possible to relate the shape of the archaeological shells to possible locations of origin by taking into account the known records for the distribution of marine mollusc species and the nature of the littoral and sublittoral substrates in Southampton Water and the Solent.

The type of hard objects on which oyster larvae settle (cultch) today was compared with those examples still remaining attached to the Hamwic shells. The indications were that a variety of both intertidal and sublittoral oyster beds, on hard and soft substrates, in Southampton Water and the Solent could have been exploited by the inhabitants of Hamwic, although intertidal beds on Weston Shore and Hamble Spit would have provided the most convenient source of oysters.

The evidence from infestation, especially by Polydora spp, tended to confirm the conclusions drawn from the analysis of shape and its relation to substrate type. The occurrence of sealed-off boreholes is a further indication that oyster beds further afield, possibly in the West Solent, were being fished. The high frequency of boreholes in the slow-growing shells from contexts 11151 and 11275 was thought to provide a plausible explanation for the anomalous age composition of the samples. The slow rate of shell formation could have meant that they were less able to withstand predation by tingles and whelks. In some years there could have been heavy mortalities. In the West Solent there is evidence that 25% of oysters between 30 and 45mm are killed by oyster drills (tingles) in the course of one summer in some areas (Key and Davidson, 1981). The fast-growing shells of context 896 also show high numbers of sealed boreholes but show a normal age distribution.

Finally, the other molluscs associated with the oyster shell deposits were considered. The rather widespread and general distribution of winkles and mussels, which occurred in the largest quantities, means that they could not be effectively used in the same way as oysters to suggest areas exploited for shellfish.

A constraint on the interpretation of the data, especially regarding changes of growth rate with time, was the fact that only one sample was examined from the early phase and one from the late phase, with the majority of samples falling into the undifferentiated mid phase. Since the shells also comprised only about a third of the excavated material, it would have been interesting to determine how representative they were of the whole and to examine modern specimens of oysters from known locations to see if growth rates, for example, were related not only to temperature changes but also to the location of the oyster bed. [N.B. Since this was written in 1985, some data have been made available through the Ministry for Agriculture, Fisheries and Food at Lowestoft for modern, natural oyster populations in the Solent and this information has been used in subsequent work.]

The pilot study of the oyster shells from excavations on the Six Dials site of Saxon Southampton demonstrated variability on an **intrasite** level between contexts and phases. In the next phase of the work, which will be described in Chapters 5 to 8, samples from a number of other sites belonging to different periods and from various regions were also studied to see if intrasite variability in oyster shells was a common phenomenon and also to build up a database by means of which **intersite** comparisons could be carried out. Chapter 5 contains details of results obtained for oyster shell samples from Newport Roman villa on the Isle of Wight; the Iron Age and Romano-British site at Owslebury near Winchester; and a 19th-century site at 11 The Hundred in Romsey. All these sites, like Six Dials, were in the Southampton region.